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ABSTRACT

What are creative people like? There is evidence that four personality traits appear to differentiate more creative from less creative people: devotion to work, independence, drive for originality, and flexibility. Creative people do not have higher intelligence quotients (IQs) or get better school grades than others--in fact, no cognitive abilities have been identified which reliably distinguish between creative and non-creative people. All of the variables which discriminate between creative and non-creative people are motivational. What cognitive factors are involved in creative acts? Years of preparation are essential for creative activity in many fields. Goal setting is the critical element in many creative acts. Other factors are: choosing good problem representations, defining good problems in ill-defined problem situations, accurately evaluating the shortcomings of your own work, and taking effective action to revise these shortcomings. The failure of cognitive ability measures such as IQ to predict creative performance indicates that creative performance has its origin not in innate cognitive abilities but rather in the motivation of the creative person. That is, differences in creativity have their origin in differences in motivation. Over a period of time, these differences in motivation cause cognitive differences (such as the acquisition of extensive knowledge) which contribute in critical ways to creative performance. These motivational and cognitive differences jointly account for the observed differences between creative and non-creative individuals, but the origin is in motivation, not in cognition. (Forty-one references are attached.) (SR)

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Occasional Paper No. 18

COGNITIVE PROCESSES IN CREATIVITY

John R. Hayes

January, 1990

University of California, Berkeley
Carnegie Mellon University

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COGNITIVE PROCESSES IN CREATIVITY

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"Creative" is a word with many uses. Sometimes it is used to describe the potential of a person to produce creative works whether they have produced any work as yet or not. Sometimes it is used to describe every-day behaviors as, for example, when a nursery school curriculum is said to encourage creative activities such as drawing or story telling. In this essay, I will restrict the meaning of the term in two ways: First, I will be concerned solely with creative productivity, that is, with creativity expressed in the actual production of creative works and not with the unexpressed potential for producing such works. Second, I will be concerned only with creative acts at the highest level, that is, with the best and most valued works of our artists, scientists, and scholars.

Society defines creative acts through a complex process of social judgment. It relies most heavily on the opinions of relevant experts in making such judgments--music critics, art historians, scholars, and scientists who are presumed to know the field. But even expert judgments are highly subjective and are frequently influenced by irrelevant factors. For example, they are influenced by the experts current focus of attention, (Gregor Mendel had to wait decades before the appropriate experts recognized that his work was important), and by the reputation of the creator, (It is hard for an unknown writer to get a publisher's attention).

Despite the vagaries of such judgments, there appears to be a core of three evaluations which underlie the identification of a creative act. These are: 1.) the act must be seen as original or novel, 2.) the act must be seen as valuable or interesting, and 3.) the act must reflect well on the mind of the creator. All three of these criteria appear to be essential if an act is to be considered creative. No matter how well executed a work may be, it will not be considered creative unless it incorporates substantial new ideas not easily derived from earlier work. Thus, even the best copies of paintings are not judged creative, not, at least, if the source is known. And no matter how original an act is, it will not be considered creative unless it is also judged to be valuable. A composer may arrange notes in a novel and unexpected way, but the work will not be considered creative unless it is also judged to have musical value. Finally, an act will not be judged creative unless it reflects the intelligence of the creator. If a work is produced entirely accidentally, then it is not judged creative. This does not mean that chance can't play a role in genuinely creative acts. Austin (1978) makes an interesting distinction among four kinds of chance events. Chance I is just blind luck. It could happen to anyone and doesn't depend on any special ability of the person it happens to. In chance II, luck depends on the persons curiosity or persistence in exploration. The fact that a curious person attends more, say, to the habits of beetles makes them more likely to discover something interesting about beetles than a person who regards them simply as something to be squashed. In chance III, luck depends on the person having extensive knowledge of the field not shared by most people. Thus, the Curie's discovery of radium depended on their recognizing that a certain mineral was more radioactive than it ought to be on the basis of the known elements it contained. Clearly only a very knowledgeable person could make such a discovery. This is the sort of chance that Pasteur was talking about when he said, "...chance favors only the prepared mind." Finally, in chance IV, luck depends on the person's particular, and perhaps unique, intellectual style or pattern of interests. Acts which involve chance events of the last three kinds do reflect credit on the mind of the actor and thus are potentially creative.

In the remainder of this chapter, I will discuss data bearing on two major questions: "What are the characteristics of creative people?" and "What cognitive processes are involved in creative acts?" Finally, I will present a theoretical framework to account for these data.

Characteristics of Creative People

Do creative people have high IQs? Yes and no.

It is often assumed that creativity is closely related to I.Q. Indeed, both Roe (1953) studying eminent physicists, biologists, and social scientists and MacKinnon (1968) studying distinguished research scientists, mathematicians, and architects found that the creative individuals they studied had I.Q.s ranging from 120 to 177 --well above the general average. However, these higher than average I.Q.s can not be taken as an explanation of the observed creativity and indeed may be unrelated to it.

Several studies indicate that highly creative individuals in a field do not have higher I.Q.s than matched individuals in their field who are not judged to be creative. Harmon (1963) rated 504 physical and biological scientists for research productivity and found no relation between creativity and either I.Q. or school grades. Bloom (1963) studied two samples of chemists and mathematicians. One sample consisted of individuals judged outstandingly productive by colleagues The other consisted of scientists who were matched in age, education, and experience to the first sample, but who were not judged outstandingly productive. While the first group outpublished the second at a rate of eight to one, there was no difference between them in I.Q. In a similar study, MacKinnon (1968) compared scientists, mathematicians, and architects who had made distinguished contributions to their fields with a matched group who had not made distinguished contributions. There was no difference between the two groups in either I.Q. or school grades.

How can it be that creative scientists and architects have higher than average I.Q.s and yet I.Q. does not predict which of two professionals will be the more creative? At least two alternative theories seem plausible. I will call the first alternative, the "threshold theory". According to this theory, a person's IQ must be above some threshold value, say 120, if that person is to be successful in creative activities. Above the threshold level, however, IQ differences make no difference in creativity. The reason that there is no correlation between IQ and Creativity among professionals is that schooling weeds out professionals with IQs less than 120.

I have proposed an alternative theory which I call the "certification theory" (Hayes, 1978). According to the certification Theory, there is no intrinsic relation between creativity and IQ. However, being creatively productive depends on getting a job in which one can display creativity -- a job such as college professor, industrial chemist, or architect. Being considered for these jobs typically requires a college or graduate degree. Since school performance is correlated with IQ, it may be that one's opportunity to be creative depends on IQ simply because of the degree requirement. Thus, creative people may not need a high IQs to be creative but they may need them to be certified to get jobs where they can put their creativity to work.

This second alternative is worth considering, because if it is correct, or even partly correct, our society may inappropriately be discouraging a large portion of the creative individuals in the population.

Other cognitive and personality traits

A large number of studies have been conducted to identify cognitive and personality traits which characterize creative people. Surprisingly, studies of cognitive traits have generally yielded disappointing results. Perhaps most disappointing are the results on divergent thinking. Divergent thinking is widely believed to be an important part of the creative process (Guilford, 1967) and measures of divergent thinking constitute a major component in the most popular creativity tests, e.g., the Torrance Tests of Creative Thinking. However, Mansfield and Busse (1981), reviewing studies of divergent thinking in scientific thought, conclude that there is essentially no evidence relating divergent thinking to creative performance in science.

Mansfield and Busse (1981) also reviewed studies of 16 other cognitive tests and concluded that none "has consistently shown high correlations with measures of real-life creativity." Researchers have been more successful in identifying personality traits in creative people. I will review evidence concerning four traits which appear to differentiate more creative from less creative people: devotion to work, independence, drive for originality, and flexibility.

Devotion to work

One of the most consistent observations about creative people is that they work very hard. Roe (1951), who studied a group of top ranked physicists and biologists, described them this way:

> "There is only one thing that seems to characterize the total group, and that is absorption in their work, over long years, and frequently to the exclusion of everything else. This was also true of the biologists. This one thing alone is probably not of itself sufficient to account for the success enjoyed by these men, but it appears to be a *sine qua non*."

Chambers (1964) and Ypma (1968), also report that creative people work harder than others. Harris (1972) reports that University of California professors spend an *average* of 60 hours weekly on teaching and research. Herbert Simon, 1978 Nobel Laureate in economics, spent about 100 hours per week for years doing the work for which he eventually won the Nobel Prize (Personal communication).

Independence

Researchers have consistently found that creative people have a strong drive for independence of thought and action. In particular, they seem to want very strongly to make their own decisions about what they do. Chambers (1964) finds that the creative scientist "... is not the type of person who waits for someone else to tell him what to do, but rather thinks things through and then takes action on his own with little regard to convention or current "fashion." (P. 14) He also finds, "When seeking a position, ... the overwhelming choice for the creative scientists is the opportunity to do really creative research and *to choose problems of interest to them.*" (P. 6) (Italics added)

MacKinnon (1961) found that creative architects also strongly preferred independent thought and action to conformity. Ypma (1968) found that creative scientists were more likely than other scientists to say that they would like to have "a good deal of responsibility" in their jobs. Further, Ympa found that creative scientists were much more likely than others to answer "yes" to the question, "Did you ever build an apparatus or device of your own design on *your own initiative* and not as part of any *required* school assignment during your later school years?" (Here, "later school years" refers to high

school and college.) This last result is interesting in the light of the success that the Westinghouse Science Talent Search has had in identifying outstandingly creative scientists. The Westinghouse Science Talent Search has selected 40 high school students each year since 1942 on the basis of self-initiated projects rather than written tests or grades. The projects are then evaluated for excellence by two scientist in the project's field. In the group of 1520 students selected between 1942 and 1979, there are five Nobel prize winners, five winners of MacArthur Fellowships, and two winners of the Fields Medal in Mathematics. This remarkable performance suggests that the tendency to initiate independent action is, indeed, an important trait of the creative person and that it may be exhibited quite early in the person's career.

The drive for originality

Since creative acts are by definition original, it wouldn't be surprising if creative people showed a special drive to be original. In fact, that is just what research has shown. MacKinnon (1963) describes the typical creative architect in his study as, "... satisfied only with solutions which are original and meet his own high standards of architectural excellence..." Ypma (1968) found that when they are asked about their major motivations, the more creative scientists were likely to answer, "To come up with something new." Barron (1963) and Bergum (1975) have made similar observations.

Flexibility

Helson and Crutchfield (1970) administered the California Psychological Inventory to 105 mathematicians who had been rated for creativity by other mathematicians. The more creative mathematicians scored significantly higher on the flexibility scale than did the less creative mathematicians.

In an extensive review of research on creativity in engineers, Rouse (1986) also found that flexibility was strongly correlated with creative performance. Creative engineers tended to mix algorithmic and associative thinking and to represent knowledge both visually and symbolically.

What Cognitive Processes are Involved in Creative Acts?

In this section, I will present an analysis of creative acts in terms of familiar cognitive processes, that is, in terms of processes that are involved in everyday thought and action. Before doing so, though, I should note that there are (at least) two points of view which hold that such an analysis is impossible. The first of these is that creative acts are, in principle, unanalyzable and the second, that creative acts involve special processes which are not involved in other kinds of thought.

Are creative processes unanalysable?

Karl Popper asserts quite forcefully that the process of scientific discovery is indeed unanalyzable. In *The Logic of Scientific Discovery* (1959), Popper says on pages 31-32,

> "The initial stage, the act of conceiving or inventing a theory, seems to me neither to call for logical analysis nor to be susceptible of it."
>
> "...My view of the matter, for what it is worth, is that there is no such thing as a logical method of having new ideas, or a logical reconstruction of this process. My view may be expressed by saying that every discovery contains 'an irrational element,' or 'a creative intuition,' in Bergson's sense."

In their book, *Scientific Discovery: An Account of the Creative Processes,* Langley, Simon, Bradshaw, and Zytkow (1987) present a position directly challenging Popper's view. These authors argue that it is indeed possible to account for scientific discovery in terms of well specified heuristic procedures. In particular, they hold that discoveries are achieved when the scientist applies sensible heuristic procedures in drawing inferences from data. They argue quite convincingly for the adequacy of this view by incorporating such heuristics in computer programs, and showing that these programs can induce well known scientific laws from data. For example, one program, BACON.1, incorporates the following search heuristics:

- Look for variables (or combinations of variables) with constant value.
- Look for linear relations among variables.
- If two variables increase together, consider their ratio.
- If one variable increases while another decreases, consider their product.

When provided with appropriate data, this program successfully induced Boyle's law, Kepler's third law, Galileo's law, and Ohm's law. Lenat had demonstrated earlier (Lenat,1976) that a well specified set of heuristics, incorporated in his program, AM (for Automated Mathematician), could make interesting discoveries in mathematics. For example, AM discovered de Morgan's laws, the unique factorization of numbers into primes, and Goldbach's conjecture.

Of course, these results don't mean that human creative processes can be accounted for entirely in terms of such search heuristics. If a person did make a discovery by applying search heuristics to data, it would still be interesting to ask what motivated the person to examine that data. However, the results do demonstrate the plausibility of accounting for an important part of the creative process through common sense search heuristics.

Is there a special creative process?

At present, the special process view appears to have achieved "straw man" status in the scientific literature on creativity. It is much more frequently attacked than defended. Further, there are no live candidates for "special creative process" that have substantial empirical backing. While we should not rule out the possibility that such special processes may someday be discovered, we should continue to exercise a healthy skepticism toward candidates which are proposed in the popular press, e. g., "lateral thinking", "right brain thinking", etc. Parsimony appears to be serving us well in this area.

The "Nothing-Special" position

This position, due primarily to Herbert Simon and his coworkers (Simon (1966); Newell, Shaw, and Simon (1964)), holds that creative acts are a variety of problem solving and that they involve only those processes which are also involved in everyday problem solving activities. According to this view, creative acts are problem solving acts of a special sort. First, they are problem solving acts which meet criteria such as those above -- that is, they are seen as novel and valuable and they reflect the cognitive abilities of the problem solver. Second, they typically involve ill-defined problems -- that is, problems which cannot be solved unless the problem solver makes decisions or adds information of his or her own.

Ill-defined problems occur frequently in practical settings. For example, in architectural practice, the client typically specifies a few of the properties of a building to

be designed but the architect must supply many more before the design problem can be solved.

To describe creative activities as problem solving needn't but to many does suggest that creation happens only when the creative person is in some sort of trouble. To an extent, this is true. Necessity *is* the mother of invention -- at least, of *some* invention. But, there are other sorts of situations which lead to creation. Creators aren't always digging themselves out of trouble. In many cases, it is reasonable to think of them as taking advantage of opportunities -- of recognizing the possibility of improving what is currently a satisfactory situation. Whether an individual is exploring an opportunity or resolving a difficulty, the important point is that they are setting goals and initiating activities to accomplish those goals.

Having reviewed the alternative points of view, I will now return to the analysis of creative acts in terms of familiar cognitive processes. Below, I will discuss a variety of cognitive processes for which there is either data or plausible inference to suggest that it is especially important in creative acts.

Preparation

There is very wide agreement among researchers that preparation is one of the most important conditions of creativity (Wallas, 1926; Ypma, 1968; Mansfield & Busse, 1981). By preparation, we refer to the effort of the creative person, often carried out over long periods of time, to acquire knowledge and skills relevant to the creative act. Hayes (198) has provided strong evidence that even the most talented composers and painters, e.g., Mozart and Van Gogh, required years of preparation before they began to produce the work for which they are famous. Hayes surveyed all of the composers mentioned in Schonberg's *The Lives of the Great Composers* (1970) for whom there was sufficient biographical data to determine when they first became seriously interested in music, e.g., began piano lessons in earnest. Seventy six composers were included in the study. Next, he identified the notable works of these composers and the dates on which they were composed. (He defined a notable work for this study as one for which at least five different recordings were currently available). From these data, he calculated when in the composer's career, that is, how many years after the onset of serious interest, each work was composed. Out of more than 500 works, only three were composed before year ten of the composers career and these three were composed in years 8 and 9. Averaged over the group, the pattern of career productivity involved an initial ten year period of silence, a rapid increase in productivity from year 10 to year 25, a period of stable productivity from year 25 to about year 45 and then a gradual decline.

In the same paper, Hayes reported a parallel study of 131 painters using biographical data to determine when each became seriously involved in painting. He defined the notable works of these painters as ones which were reproduced in any of 11 general histories of art. The pattern of career productivity for the painters was similar to that observed in the composers. There was an initial period of silence lasting about six years. This was followed by a rapid increase in productivity over the next six years, a period of stable productivity until about 35 years into career and then a period of declining productivity.

Wishbow (1988) conducted a biographical study similar to those just described of 66 eminent poets. For her study, she defined a notable poem as one included in the Norton Anthology of Poetry. She found that none of her 66 poets wrote a notable poem earlier than five years into their careers and 55 of the 66 produced none earlier than ten years into their careers.

The early silence observed in all three of these studies suggests that a long period of preparation is essential for creative productivity even for the most talented of our composers, painters, and poets. In conducting this research, both Hayes and Wishbow encountered considerable skepticism expressed by experts in music, art, and literature that such investigations could produce any consistent result. The skepticism was based on the following very reasonable argument:

1. These studies included individuals of very diverse esthetic orientations, e.g., Wagner and Satie, who were attempting to do very different things.

2. These studies included individuals from four different centuries (the 17th through the 20th) who produced their works in very different social contexts.

3. Therefore, there is no reason to expect that there would be consistency in the conditions favoring creative performance across such diverse times and groups.

There is nothing logically wrong with this argument. It might be that differences in social context and esthetic goals would dominate all other conditions of creative productivity. As it turns out, they don't. Creators appear to require a long period of preparation despite differences in time and esthetic objectives.

What is this period of preparation used for? Simon and Chase (1973) observed that chess players require about ten years of preparation before they reach the level of grand master. They suggest that during this time, the serious player learns a vast store of chess patterns through hundreds of hours devoted to study and play. They estimate that a player needs to know roughly 50,000 chess patterns in order to play at the grand master level. One can easily imagine that composers, painters, and poets need a comparable period of time to acquire sufficient knowledge and skills to perform in their fields at world class levels.

Goal setting

Goal setting often appears to be the most critical element in a creative act. According to Einstein and Infeld (1938):

> "Galileo formulated the problem of determining the velocity of light, but did not solve it. The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill. To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science."

Pavlov's discovery of the conditioned reflex is another case in point. As part of a study of digestive processes, Pavlov was investigating the salivary reflex in dogs. Dogs salivate automatically when food is placed in their mouths. The experiment went well at first, but after a while, the dogs began to salivate before the food was placed in their mouths. This development seriously complicated the study that Pavlov was trying to carry out. However, rather than seeing it as an annoyance to be eliminated, he saw it as an interesting phenomenon to be investigated. Against the advice of his colleagues, he abandon his original objective and set a new goal which lead to his historic work on the conditioned reflex.

Janson (1983) claims that Manet's painting, *Luncheon on the Grass*, was historically significant because it was "a visual manifesto" of a new set of goals--goals which emphasized the importance of visual effects on the canvas in contrast to social or literary

"meanings" which a painting might convey. He says, "Here begins an attitude that was later summed up in the doctrine of Art for Art's Sake ..." P607.

Of course, goal setting isn't always difficult. There are many situations in which the goals are obvious even though the means for achieving them are not. Everyone knows that curing cancer and reducing auto accidents are valuable goals to strive for. What distinguishes the creative people in the examples given above is that they recognized an opportunity or a problem when other people did not. What might be responsible for differences in peoples ability to find problems or to recognize opportunities? Since we know very little about such processes, any account must admittedly be speculative. Here are some hypotheses:

1. Extensive knowledge of a field should give one increased ability to recognize both opportunities and problems by analogy to previous experience. For example, if a chess situation resembles one the player has been in before, it could signal an opportunity if the previous outcome was favorable, and a problem if it was not.

2. A unique pattern of knowledge outside of a field, acquired perhaps through hobbies or through switching professions, could provide a person with analogies not generally available to others in the field. Such analogies could suggest unsuspected possibilities or problems in the field. Consistent with this view, Gordon (1961) recommends that problem solving teams in industry should include people from very diverse fields.

3. Strong evaluation skills may lead one to recognize problems in a line of research that others fail to recognize and as a result to initiate new studies that others would not have thought of. Evaluation skills in the social sciences seem to depend heavily on the sorts of critical thinking skills taught Huck and Sandler's *Rival Hypotheses* (1979). Perhaps some aspects of creative performance could be improved through training in these skills.

These hypotheses could be viewed as examples of the operation of Austin's Chance III and Chance IV.

Representation

Since tasks which allow scope for creativity are typically ill-defined, a person doing such a task is forced to make many choices in building a representation of the task. For example, an architect may be given the task of designing a shop together with specifications of the location, size, type of merchandise to be displayed, clientele, etc. To represent the design problem in sufficient detail so that it can be solved, the architect must make a great many decisions. For example, he may decide that the shop should have a certain kind of access, should be "transparent", and should have "levels" (See Hayes, 1978 pp. 206-210). Ill defined problems offer a great deal of latitude in the way they can be represented or defined.

The way one represents a task can have a critical impact on how hard the task is to do or even whether it can be done at all. Kotovksy, Hayes, and Simon (1987) showed that a problem represented in one way may be 16 times as hard to solve as the same problem represented a different way. The 16 to 1 range almost certainly underestimates the full range over which changes in representation can change problem difficulty. Thus, choosing to represent a problem visually rather than verbally, or choosing to represent the problem by one metaphor rather than another could make a sufficient difference in problem difficulty that one scholar may be able to solve the problem and another not. In some cases

then, the creative person--the one who solved the problem when others couldn't-- may be the person who chose the the best representation of the problem.

Kotovsky, Hayes, and Simon (1985) were comparing different representations of the *same* problem. Even though the problem solvers' representations of the problem were different in the sense that a problem element might be represented as a position in one case and as a size in another, the underlying problem was always the same. It is rare, though, for two people, acting independently, to define an ill defined problem in the same way. If two architects were commissioned to design the same house, they would almost certainly interpret that commission in different ways, placing different emphases on the various design requirements. Each architect would define his or her *own* design task. It is tempting to speculate that creative people define "better" or "more interesting" tasks for themselves than do less creative people.

While there are no studies comparing task definition in creative and non-creative people, there are some task definition studies comparing experts and novices. These studies show that a very important part of the difference between experts and novices may lie in the way they define the task to be performed. Hayes, Flower, Schriver, Stratman, and Carey (1987) found that novice writers represented the task of revision as a sentence level task. That is, they attended to each sentence separately, fixing the grammatical and lexical problems it contained, and concerned themselves rarely or not at all with global problems such as transitions, coherence, and the effectiveness of the whole text. The experts, in contrast, were primarily concerned with the global problems although they fixed the local problems as well. The experts did a far better job of revision than did the novices, and it seems clear in this case that their better performance depended on their having defined a better task for themselves. One can't really expect to do a good job of revision with a task definition that ignores a very important class of problems. Carey and Flower (This volume) provide an excellent discussion of how expert-novice differences in task definition influence expository writing. While these expert-novice studies can't be taken as proof, they do make it seem plausible that creative people may differ from less creative people in part because they define better tasks for themselves.

Searching for solutions

Many approaches to improving creative thinking such as brainstorming (Osborne, 1948) and Synectics (Gordon, 1961) focus on the fostering of divergent thinking, that is, on generating many alternative solutions to the same problem. These techniques appear to be useful for some kinds of group problem solving (Stein?). However, as was noted above, divergent thinking skills appear to be unrelated to the sort of creative productivity that this chapter is concerned with.

It is interesting to contrast the emphasis in the creativity literature on the importance of generating many solution paths with the emphasis in the cognitive science literature (See Newell and Simon, 1972) on the importance of heuristic search, that is with narrowing many solution paths down to a few to. Perhaps high level creative creative activities are more likely to demand heuristic search than divergent thinking.

In an early, but still influential discussion of creativity, Wallas (1926) claimed that incubation is one of the characteristic stages of the creative process. By incubation, he meant a stage in which the problem solver has stopped attending to the problem but during which progress is being made toward the solution anyway. Researchers have attempted to demonstrate the reality of the phenomenon with experiments of this sort: Experimental and control subjects are given a complex problem to solve. The control subjects are allowed to work continuously on the problem until they solve it. The experimental subjects are interrupted in their solution efforts and asked to attend to another task for a period of time

before they are allowed to return to the problem and solve it. If the experimental subjects required less total time *working on the problem* to solve it than the control subjects, that would be taken as evidence of incubation. While a number of early investigators failed to obtain positive results with this experiment Cook (1934, 1937) and Ericksen (1942), more recent experimenters have obtained positive results (Fulgosi & Guilford, 1968; Murray & Denny, 1969; Silviera,1971).

The success of these experiments, however, can't be taken as definite proof that incubation occurred. The problem, as Ericsson and Simon (1984) point out, is that is very difficult to establish that the experimental subjects obeyed (or, indeed, could obey) instructions not to attend to the problem during the incubation period.

Even if incubation is a real phenomenon, it doesn't follow that it is a characteristic stage of the creative process. Hayes (1978) reanalysed the data on which Wallas based his conclusions (the testimony of creative individuals) and found many instances in which creative acts proceeded from beginning to end without any pause that would allow for incubation. While Wallas' claims for incubation are interesting, it appears that there is little empirical evidence to support them.

Revision

In performing skilled activities, people often stop to evaluate what they have produced and to improve on any shortcomings they may find. This revision process appears to be especially important in creative activities because of the very high standard involved. Murray, a Pulitzer prize winning essayist, speaks eloquently about the importance of revision. "Rewriting is the difference between the dilettante and the artist, the amateur and the professional, the unpublished and the published. William Glass testifies, "I work not by writing but rewriting." Dylan Thomas states, "Almost any poem is fifty to a hundred revisions--and that's after it's well along." Archibald MacLeish talks of "the endless discipline of writing and rewriting and rewriting." (Murray, 1978, P85)

Revision, of course, is not confined to writing. It happens in the development of scientific theory, in painting, and in musical composition. For example, in a letter, Tchaikovsky says, "Yesterday, when I wrote you about my method of composing, I did not enter sufficiently into that phase of the work which relates to the working out of the sketch. This phase is of primary importance. What has been set down in a moment of ardour must now be critically examined, improved, extended, or condensed, ..." (Quoted in Vernon, 1970, P59)

If revision is an important part of creative activity, it is reasonable to expect that creative people may be better at revision than are others. While evidence on this issue is scant at best, the question is interesting enough to pursue. There are at least three possible factors which might make creative people superior revisors:

1. Creative people may have higher standard for performance than others.

While this is a very plausible assertion, it validity has been tested only in the area of standards for creativity. As was noted above, creative people aspire more than others to be creative. The impact that this might have on performance is illustrated in a study carried out by Magone (Personal Communication). Magone collected think-aloud protocols of people who were taking a creativity test in which they were asked to complete a drawing in as many different ways as they could. She found that people who scored high on the test were much more likely than those who scored low to reject ideas as "trite" or "boring". While this creativity test probably does not predict real creativity, the study does illustrate the point that high standards for creativity can shape performance.

2. Creative people may be more sensitive than others in perceiving that standards have not been met.

There are no studies comparing creative people with others in this skill. However, Hayes, et al. (1987) have found that expert writers were far more sensitive detectors of text problems than were novices.

3. Experts may be more flexible than others in considering change.

Results of personality surveys, cited above, suggest that creative people are, in fact, more flexible than others. Flexibility could increase ones chances of performing creatively in a number of ways: A more flexible person might be more likely than others to drop everything to pursue a hot new lead as Pavlov did in the example presented earlier. A flexible person might be more likely than others to sacrifice less important goals in order to accomplish more important ones. And a more flexible person might be more likely than others to change problem representation if progress toward solution is unsatisfactory.

Discussion

In this chapter, we have explored two major questions. In answer to the question, "What are creative people like?", we found fairly good empirical evidence to support the following conclusions:

1. Creative people work very hard.

2. Creative people are more disposed to setting their own agenda and to taking independent action than are others.

3. Creative people strive for originality.

4. Creative people show more flexibility than others.

5. Creative people do not have higher IQs or get better school grades than other when we control for age and education. In fact, no cognitive abilities have been identified which reliably distinguish between creative and non-creative people.

The surprising thing about these findings is that all of the variables which discriminate between creative and non-creative people are motivational. No cognitive abilities have been discovered which discriminate between these two groups.

In exploring the question, "What cognitive factors are involved in creative acts?", we have uncovered convincing evidence on two points:

1. Years of preparation are essential for creative productivity in many fields.

2. Goal setting is the critical element in many creative acts.

In addition, plausible arguments can be made for the importance of the following in creative acts:

1. Choosing good problem representations.

2. Defining good problems in ill defined problem situations.

3. Accurately evaluating the shortcoming of one's own work.

4. Taking effective action to revise the shortcomings.

Clearly, both cognitive and motivational factors are involved in creative performance. However, the failure of cognitive ability measures such as IQ to predict creative performance leads me to propose that creative performance has its origin not in innate cognitive abilities but rather in the motivation of the creative person. Over a period of time, this motivation has cognitive consequences, such as the acquisition of large bodies of knowledge, which contribute in critical ways to creative performance, but the *origin* is in motivation, not cognition.

The motivation of the creative person may be thought of as a vector which is special both in strength and direction. Motivation of great strength is necessary because creative people face daunting tasks. They must work for many years, perhaps for a decade or more, before they can begin to accomplish their creative goals. They may have to reject easily available rewards in order to pursue their fields. One of my students said, "I must like art a lot to be willing to go to school for four years in order to be out of work". They may sometimes have to face active opposition as Pavlov did.

The direction of motivation is as critical as its strength. Success in many areas of life requires strong motivation and hard work. In many practical situations, the hard work must be directed to satisfying the demands of a boss or the standards or interests of the public. Creative people, however, are motivated to be in charge of their own actions, and through those actions, to do something that hasn't been done before, perhaps hasn't even been thought of before.

The nature of their motivation may lead creative people to take different paths than others take. For example, creative people may choose fields, such as the arts or sciences, where they believe they can exercise their interest in creative activities, rather than sales or medical practice where creative activities may not be appreciated.

Motivational differences can result in important differences in cognitive factors. If a person is willing to work longer and harder than others, he or she can acquire a larger body of information than others. In solving a problem, this extra information might be used directly to make an essential inference or might provide an analogy that would suggest a solution path. Willingness to work hard could also lead a person to define harder and better problems for themselves and in general to set higher standards for themselves. Higher standards could lead one to be more critical of shortcomings in one's work. Motivation to be independent would predispose a person to set their own goals and motivation to be creative would lead them to reject goals that were "trite" or "boring".

Finally, motivation to be flexible could make it easier to change direction completely when a new opportunity presents itself, to sacrifice minor objective to accomplish major ones, and to change representation when progress is unsatisfactory. The primary thrust of the position that we are presenting here is that differences in creativity have their origin in differences in motivation. These differences in motivation then cause cognition differences and these motivational and cognitive difference jointly account for the observed differences between creative and non creative individuals.

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